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Stability of Ag island films deposited on softened PVP substrates

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Abstract : The results of the aging studies carried out on island silver films deposited on Poly(2-Vinylpyridine) (PVP) coated glass substrates held at temperatures above the glass transition temperature of PVP are reported in this article The instability or aging of island silver films reduced considerably on softened PVP substrates compared to films on rigid substrates. This is attributed to the formation of sub-surface particulate structure, which is confirmed by X-ray Photoelectron Spectroscopy (XPS)

Keywords : Island films, PVP, aging, XPS

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1. Introduction

A discontinuous metal film deposited on a dielectric substrate may be regarded as a system of randomly distributed metallic and dielectric regions. These films have attractive electrical properties which can be exploited for device applications like high sensitivity strain gauges, temperature sensors *etc.* But, the main hurdle is their temporal instability or aging, which manifests itself as an irreversible resistance increase with time, even in vacuum. Aging is attributed to the mobility of islands followed by coalescence, leading to an increased inter-island spacing [1].

It is reported that vacuum deposition of materials such as Se, Sn, In *etc.* onto softened polymer, results in the formation of sub-surface particulate structure [2]. The morphology of such sub-surface structure is dependent on deposition factors and polymer metal interaction [2,3]. The studies on the electrical properties of island films deposited on softened substrates are sparse. The dispersion of very small particles can be obtained in a PVP matrix due to the interaction of lone pair from nitrogen atom in PVP with silver [3]. Therefore, one can expect that silver island films deposited on softened PVP substrates

would result in reduced aging. In this paper we present the results of studies carried out on the aging of silver island films deposited on PVP substrates, held at a temperature much above the glass transition temperature.

2. Experimental details

Silver (purity better than 99.99%) films of various thicknesses were evaporated onto PVP coated glass substrates held at 425 K and 455 K in a vacuum of 8×10^{-6} torr. The film dimensions were 1 cm × 1 cm. A Chromel Alumel thermocouple was used to measure the substrate temperature. A quartz crystal monitor was used to measure the deposition rate as well as the thickness of the material deposited. The deposition rate was 0.4 nm/s for all the films. The film resistance was measured using a Keithley DMM 2001. XPS was used to determine the formation of sub-surface structure.

3. Results and discussion

Figure 1 shows the variation of normalized resistance with time for various film thicknesses at 425 K and 455 K. An aging curve for the film deposited on PVP at room temperature is

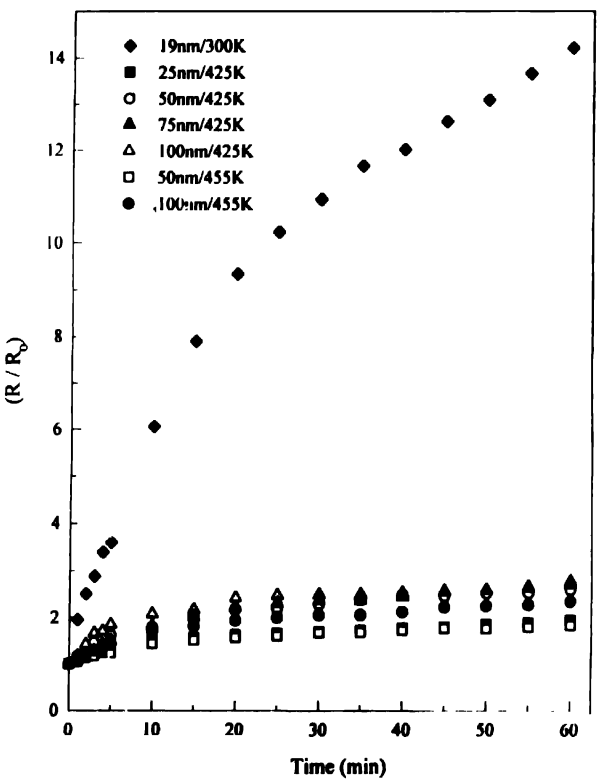

Figure 1. Variation of normalised resistance with time for silver films deposited on PVP substrates.

also given in the same figure for comparison. The variation of resistance on a softened substrate is considerably reduced when compared to a film on a rigid substrate. Figures 2

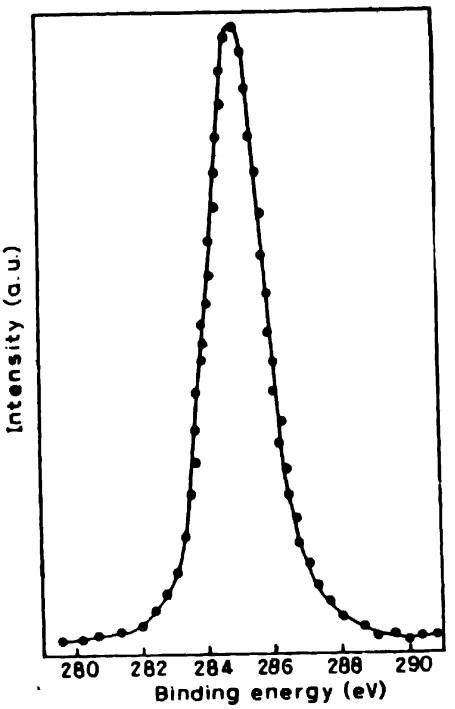

Figure 2. C 1s core level XPS spectrum at two different ETO As for Ag on PVP Continuous line-75°, filled circles-45°

and 3 show the C 1s and Ag 3d XPS spectra for a typical silver film deposited on PVP held at 425 K at two electron take off angles (ETOA defined as the angle between electron emission and surface parallel) of 75° and 45°.

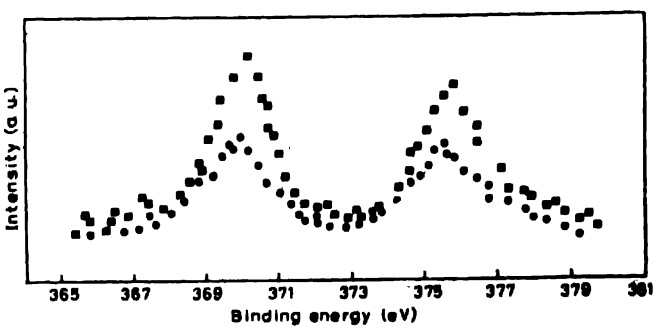

Figure 3. Ag 3d core level XPS spectrum at two different ETOAs for Ag on PVP. Filled squares-75°, filled circles-45°

The mobility coalescence model predicts the aging rate to increase with an increase in mobility. The mobility of the islands on the substrate surface is an activated process and

at higher temperature a higher aging rate is expected. But, in the case of silver deposited on PVP held at 425 K and 455 K, the aging is considerably less when compared to a film deposited on PVP at room temperature (Figure 1). This deviation can be readily understood if one assumes that the silver islands are formed beneath the PVP surface. The silver islands inside the polymer would have much lower mobility due to the polymer viscosity resulting in a reduced aging rate. Copper island films deposited on softened polymethylmethacrylate (PMMA) exhibited higher aging rate where only a surface deposit was formed [4]. Silver is known to form a sub-surface structure [2] and therefore, the reduced aging of silver clearly indicates the formation of a sub-surface structure. Further, silver deposited on rigid PVP (substrate held at room temperature) shows film continuity at a thickness of 25 nm, while films on softened PVP substrates have resistances in the range of megaohms even for a thickness of 200 nm. This is possible only when silver is dispersed inside the PVP matrix.

Angle dependent XPS studies is an useful technique for studying depth profiles. This is made possible by the small electron inelastic scattering lengths in condensed matter (typically 2–5 nm). The depth sensitivity of the spectroscopy can be changed by varying the ETOA. The C 1 s signal at two different ETOAs show little change (Figure 2) indicating that carbon is homogeneously distributed within the surface region [5]. Considerable attenuation of the Ag 3d signal is observed at a lower ETOA. This implies that the silver is buried beneath a layer of PVP [5], thus confirming the formation of a sub-surface structure. Detailed analysis of the XPS studies will be published elsewhere.

4. Conclusions

The aging of silver films deposited on softened PVP is very much less compared to Ag films on a rigid substrate indicating the formation of a sub-surface discontinuous film structure. The XPS studies at two different ETOAs confirm the formation of a sub-surface silver film.

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